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[0001] The invention relates to an internal combustion engine with a combustion chamber to the clocked combustion of a fuel bottom formation of a combustion gas, a separate expansion chamber connected with the combustion chamber over a controllable combustion chamber exhaust valve, displaceable stored pistons for the conversion of energy of the combustion gas to mechanical work and/or. Energy exhibits, and or several compressor pumps formed as piston cylinder units to the filling of the combustion chamber with compressed air, which exhibit an air intake valve in each case.

[0002] Internal combustion engines are in different embodiments known, for example as conventional petrol or diesel engines. Known ones are further internal combustion engines with one of the combustion chamber, becomes clocked combusted in which the fuel bottom formation of a combustion gas, separate expansion chamber, which is connected with the combustion chamber over a controllable intake valve. In the expansion chamber a piston displaceable journaled, by means of that energy of the combustion gas is into mechanical energy and/or. Work reacted becomes. Such internal combustion engines are for example from the EP 0,957,250 a2, at-PS 172,823, the CH-PS 202,930, the FR-PS 820,750, the DE-PS 4,136,223 and the US-PS 4.716.720 known. The advantage of these internal combustion engines consists in particular of the fact that the combustion gas in the expansion clock in the expansion chamber complete, formed with the combustion, can relax, whereby the energy of the combustion gas can become better utilized. The filling of the combustion chamber with fuel air mixture can take place with atmospheric pressure or compressed. For the compaction of the air in the combustion chamber it is already known to use own compressor pump for example from the DE-PS 4,136,223 and the US-PS 4,716,720.

[0003] With such motors the problem arises just like with conventional petrol and diesel engines that with high engine speeds and with full load of the motor by the inherent throttle effect of the intake valve and/or. the air filling way an air number of at least lambda = 1 without special measures, required for a stoichiometric combustion, no longer achieved will can. With conventional petrol or diesel engines for example turbochargers become used the overcoming of this problem.

[0004] Object of the invention is it to make an internal combustion engine to that available initially mentioned type with which in simple manner also with the highest engine speed an air number of lambda = 1 anyhow achieved can become at least. This problem becomes according to invention by the fact dissolved that the air intake valve is throttlable into the compressor pumps and that the volume of the cylinder space of the compressor pump or, in case of several compressor pumps, which is larger total volume of the cylinder spaces of the compressor pumps around at least 25%, preferably at least 50%, than it corresponds to a volume for a filling of the combustion chamber with a mixture with an air number of lambda = 1 with an amount at fuel, introduced with full load of the motor.

[0005] It becomes assured thereby that also with the highest engine speed an air number of lambda = 1 anyhow achieved can become at least, without other, conventional-proves intended expensive measures. Becomes with smaller speed of the motor and/or. with partial load an only smaller amount of air required, then can become the intake valve corresponding throttled.

[0006] An other aspect of the invention concerns an internal combustion engine with a combustion chamber to the clocked combustion of a fuel bottom formation of a combustion gas, a separate expansion chamber connected with the combustion chamber over a controllable combustion chamber exhaust valve, displaceable stored pistons for the conversion of energy of the combustion gas to mechanical work and/or. Energy exhibits, and or to valve stem disposed valve disk it covers several compressor pumps to the filling of the combustion chamber with compressed air, formed as piston cylinder units, whereby is provided as respective air intake valve into the compressor pump a cheque valve biased in closing direction.

[0007] A such Verbrennnungsmotor is for example known from the DE specified already 4,136,223 c1. Object of the invention is it to make an internal combustion engine available of this type with which the amount of air introduced into the combustion chamber is more controllable in simple manner. This succeeds according to invention thus that the air intake valve is throttlable and that the volume of the cylinder space of the compressor pump or, in case of several compressor pumps, which is larger total volume of the cylinder spaces of the compressor pumps around at least 25%, preferably at least 50%, than it corresponds to a volume for a filling of the combustion chamber with a mixture with an air number of lambda = 1 with an amount at fuel, introduced with full load of the motor.

[0008] It becomes thus a type “air spring” provided, which gives the closing force of the valve. The spring rate of this air spring is more adjustable. Cheque valve opens only if the closing force is exceeded by the negative pressure present in the cylinder of the compressor pump and the size of the opening depends on the closing force in the comparison, predetermined by the air spring, to the negative pressure in the cylinder of the compressor pump. In dependence of the closing force promoted therefore air becomes thus more or less into the cylinder of the compressor pump (a more or less large negative pressure in the cylinder space of the compressor pump is called) during the downward motion of the piston of the compressor pump at the bottom dead center of the piston of the compressor pump prevails, since also in the opened state cheque valve in dependence of the degree of its port has a certain flow resistance, so that that cannot take place influxes from air into the cylinder space of the compressor pump arbitrary rapid. This amount of air becomes compressed with the subsequent upward motion of the piston of the compressor pump into the combustion chamber.

[0009] Other advantages and details of the invention become in the following explained on the basis the accompanying drawing. In this shows:

Fig. 1 a schematic representation of a prefered embodiment of an internal combustion engine according to invention and
Fig. 2den pressure pattern in the expansion chamber.

[0010] Although in the schematic representation in accordance with Fig. 1 only a single piston 1 shown is, is prefered-proves at least two, synchronous current pistons acting on the driven shaft 2 of opposite sides 1 provided. Thereby, two or several pairs of such opposite, in each case synchronous clocked pairs of pistons 1 in respective cylinders provided can be. At least the opposite in each case pistons or also all pistons can affect thereby over the same inner and outside cam surfaces 3, 4 of the late of still precise explained cam gear and own in each case thrust members in the form of rollers disposed at the piston rods 6 the driven shaft 2.

[0011] Each piston 1 is at least a combustion chamber 7 to the clocked combustion of a fuel associated. The combustion chamber is

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surrounded of a jacket from an heat insulating material. Only in the starting phase the made ignition of the fuel air mixture by a spark plug 9. In continuous operation the walls of the combustion chamber 7 heat up over the Selbstentzündungstemperatur of the fuel (on over 700 DEG C) and the ignition of the fuel made direct with its injection into the combustion chamber 7, if it arises on their walls. Together with the fuel will prefered-proves water injected, in order to degrade the combustion temperature, which leads in particular to a NOx reduction. The injection nozzles for the fuel and the water are in Fig. 1 only schematic as unit 10 shown, whereby the supply of the fuel by the arrow V and the supply of the water are by the arrow VI indicated.

[0012] The combustion chamber 7 is over a controllable combustion chamber exhaust valve 11 with an expansion chamber separate of the combustion chamber 7 12 connected, which is formed as cylinder space, in which the piston 1 displaceable journaled is. To the avoidance of heat losses an heat insulating layer 14, 15, preferably from a ceramic material, is at the inside of the cylinder head 16 and at the expansion chamber 12 directed top of the piston 1 disposed. The cylinder wall 17 does not only exhibit such heat insulation.

[0013] To the injection of water into the expansion chamber 12 to the introduction of a implosion phase subsequent to the expansion phase, if the piston 1 has the bottom dead center UT achieved, an injection nozzle flowing into the expansion chamber 12 is 19 provided for waters. This exhibits a circular nozzle opening or several along a circumference disposed nozzle openings, whereby water becomes a bottom flat angle toward the cylinder wall 17 sprayed. This water injection serves also for the cooling the cylinder wall 17, so that a piston seal can become 18 from plastic used (preferably from graphite Teflons, which is to approximately 250 DEG C constant temperature stable). A such piston seal 18 is water lubricated.

[0014] After the injection of the water into the expansion chamber the negative pressure supported training upward on the one hand the rinse of the combustion chamber 7, on the other hand one thereby the piston 1 becomes toward its upper dead center OT pulled. The piston 1 is over the piston rod 22 with the compressor piston 21 of a compressor pump 23 connected formed of a piston cylinder unit. With the downward motion of the piston 1 and the compressor piston 21 connected thereby opens the air intake valve 24 and air formed as self-closing cheque valve flows in into the cylinder space 25. With the subsequent upward motion of the piston 1 and/or. Compressor piston 21 that opens formed air exhaust valve 29 and air, which lead to a corresponding compressor pressure, as self-closing cheque valve likewise becomes into the combustion chamber 7 pressed. On the compressor piston 21 a cushion is 20 disposed from deformable material, so that 25 pressed in the highest position of this piston all air becomes from the cylinder space, which would work otherwise than “air spring”, which would lead to unnecessary losses.

[0015] The air intake valve 24 covers a valve disk 26, which is at valve stem 27 disposed. A simultaneous piston rod of a piston cylinder unit 31 connected with a piston 28 forms 27 for the valve stem. The cylinder space 32 of this piston cylinder unit is filled with air, whereby the air pressure causes one in closing direction of the air intake valve 24 force. To the change of the closing force of the air intake valve 24 the air pressure is more variable in the cylinder space over an air pump a comprising unit 33. This air pressure represents thus a type “air spring”, whose spring rate is more variable. The air intake valve opens only if the negative pressure in the cylinder space 25 overcomes the closing force of the air intake valve 24. By the limited flowing in speed, if the compressor piston 21 has the bottom dead center achieved, a negative pressure different in dependence of the closing force of the air intake valve 24 prevails to the air by the air intake valve 24. The amount of air and thus, introduced into the combustion chamber 7 in the subsequent compressor stroke, the compressor pressure are in this way more variable.

[0016] While the piston 1 from its bottom dead center UT is connected toward its upper dead center OT moved, the incineration gas water vapor mixture in the expansion chamber, standing at the bottom dead center UT first bottom negative pressure, until its pressure finally rises over atmospheric pressure and it can leak out by opening the expansion chamber exhaust valve 30.

[0017] The expansion chamber exhaust valve 30 covers the cylinder wall 17 displaceable in longitudinal direction of the cylinder. In the closed position of the expansion chamber exhaust valve 30 the cylinder wall 17 becomes against a sealing ring disposed in an annular groove in the cylinder head 16 35 pressed, against the force of a spring 34 acting in opening direction of the expansion chamber exhaust valve. In the open position an annular exhaust port becomes released. To the application of the displaceable cylinder wall 17 into the position pressed against the sealing ring 35 is in the illustrated embodiment a cam steering provided. On the shaft 2 a cam disc is 45 provided. By the cams disposed on this cam disc 45 (apart from two depressions essentially around the entire cam disc the 45 extend; per revolution of the shaft will two clock cycles of the motor performed) becomes on around a rotational axis 36 pivotable lever 37 stored pin against a flange 13 of the cylinder wall 17 pushed. At the pivotable lever 37 disposed, on the cam disc 45 if the roller running off 44 is in one of the depressions between the cams, then the expansion chamber exhaust valve opens 30 by the force of the spring 34, and the incineration gas water mixture can leak out the expansion chamber 12. Over a piece of line of 40 it arrives into a water separator 41, which can be analogous to into the EP 0,957,250 a2 described water separator constructed. The cooling water will the corresponding arrow VIII into the water tank 42 recycled and the combustion gas can by the exhaust 43 leak out.

[0018] The combustion chamber exhaust valve 11 becomes likewise operated, whereby a roller 46, by a cam steering, which is 47 journaled to a lever arm of a pivotable lever, unreels, over a cam disc 48. The cams disposed on this cam disc 48 operate the combustion chamber exhaust valve 11 via the pin 49 connected with the other lever arm of the lever 47 and the lever 50.

[0019] The injection of the fuel and the water into the combustion chamber 7 as well as the injection of the water into the expansion chamber 12 different conventional formed pumping mechanisms used can become, for example of the shaft 2 propelled cam pumps. At the free end of the bar 5 applied of the piston 1 a roller is 6 rotatably supported. This is 4 disposed between inner and outside cam surfaces 3. The distance between the two cam surfaces 3, 4 is somewhat larger thereby as the diameters of the roller 6, so that the roller 6, which works as thrust member of the cam gear, can unreel, either on the inner cam surface 3 or the outside cam surface 4. If with the downward motion of the piston 1 from the top dead center to the bottom dead center the roller unreels 6 on the inner cam surface 3, then the shaft 2 energy supplied (by the gauge pressure of of the expanding combustion gas) becomes, if the roller 6 with the downward motion of the piston on the outside cam surface 4 unreels, then drives the shaft 2 the pistons on (thus the combustion gas in the expansion chamber 12 to bottom atmospheric pressure diluted can become, like other down still explained becomes). With the upward motion of the piston 1 of the bottom dead center toward the upper dead center made against it the energy supply to the shaft 2 in case of unreeling the roller 6 on the outside cam surface 4. When unreeling the roller 6 over the inner cam surface 3 made tapping energy (for example, if the energy should not be sufficient due to by the implosion of generated negative pressure in the expansion chamber 12, caused due to the injection of the water, for the compaction of the air by means of the compressor pump 23).
With the inner and with the outside cam surface it concerns 3, 4 in each case a extent-closed outer surface. In each case the cam surfaces 3, 4 exhibit three portions, which become in the following on the basis the inner cam surface 3 explained along their circumference. In the first portion 53 the distance of the cam surface removes 2 only rapid ones from the center of the shaft, then slower. This portion is the downward motion of the piston from the top dead center associated to the bottom dead center. The initial rapid decrease of the distance corresponds thereby to the initial rapid decrease of the pressure in the expansion chamber. In the following the distance of the cam surface 3 of the wave center increases second portion 54 again. This portion is the upward motion of the piston from the bottom dead center associated to the top dead center. Subsequent one to the second portion 54 follows a third portion 55, which exhibits a constant maximum distance of the center of the shaft 2. During the flow of the roller 6 over this portion 55 of the cam surface therefore the piston remains standing motionlessly at the top dead center OT (“wait phase”). During this time the complete combustion of the fuel in the combustion chamber can become 7 performed. The three portions 53, 54, 55 are twice provided along the circumference of the cam surface 3, so that during a complete revolution of the shaft 2 two complete working cycles and/or. Clock cycles of the motor performed become. The outside cam surface 4 is in analogous manner in the portions 53, 54, 55 divided into

respective portions.

[0020] Between the piston 1 and of the piston 1 applied, over the described cam gear the shaft 2 the propelling bar 5 is spring means 56 provided. This covers compression springs 57, which are formed as disk springs here. The compression springs are 1 disposed between a pressure plate 58 specified at the bar 5 and the back face of the piston remote of the expansion chamber 12. Around dumps of the piston 1 during its upward motion, in which it propels the compressor piston 21, are at least three compression springs provided, which are disposed at the corner points of a meant triangle, in the illustrated embodiment are four compression springs provided disposed at the corner points of a meant square, whereby the pressure plate becomes 58 formed of two crossing arms. The disk springs 57 are further 59 biased over screws. The piston 1 moved itself opposite the pressure plate therefore 58 only if this preload becomes exceeding force on the piston exerted. This prevented again a tilting of the piston with its upward motion due to on the pistons the 1 force unsymmetrical by the compressor piston 21.
To the avoidance of an unsymmetrical load of the piston 1 with its upward motion the piston rod 22 would know central at the piston 1 engage, is called with the bar 5 aligning (whereby the combustion chamber 7 other lateral would have to be shifted). In this case a single, central compression spring 57 between the bottom of the piston 1 and the bar 5 would be sufficient, whereby the bias of spring could also be void.

[0021] The spring means are in such a manner designed with the fact that it can take up in a first phase of the downward motion of the piston 1 on this from the combustion gas after opening the combustion chamber exhaust valve 11 1 pressure peak exerted on the pistons and as potential energy stores. Thus the maximum pressure reduced exerted on the bar 5 becomes, like this from the diagram of Fig. 2 apparent is. The pressure, which became exerted without the spring means 56 on the bar (and is on the piston the 1 rests), by the dotted line 60 shown. Due to the spring means the pressure pattern the corresponding solid line 61 results. The maximum pressure is thus substantial smaller. In the first phase of the downward motion of the piston of the spring means stored energy is by the hatched area 62 shown. In an other phase of the downward motion of the piston with a smaller pressure of the combustion gas this stored potential energy becomes again 5 discharged to the bar. This delivered energy corresponds to the surface 63.

[0022] The clock cycle of the internal combustion engine runs off thus as follows:

[0023] During the upward motion of the piston 1 toward its upper dead center OT fresh air becomes into the combustion chamber 7 introduced and compressed by means of the compressor pump 23. As soon as the piston 1 the top dead center OT achieved has and/or. short before it, the made injection of fuel and water into the combustion chamber 7. Only with the cold start of the internal combustion engine a made ignition over the spark plug 9. The cold start of the motor further the piston becomes 1 over the shaft 2 and the cam gear by means of an electric motor driven not represented in the fig.

[0024] After the complete burn-up of the fuel air mixture, whereby the piston 1 still at its top dead center OT is, the expansion chamber exhaust valve becomes 30 closed and the combustion chamber exhaust valve 11 opened. The pressure in the expansion chamber 12 rises thereby first rapid and drops in the sequence with downward current piston 1 gradual again. With full load enterprise the pressure in the expansion chamber 12 with a prefered operation straight dropped to atmospheric pressure, if the piston 1 has the bottom dead center UT achieved. In this case the atmospheric pressure becomes already achieved with partial load operation of the motor, while the piston 1 is still on its path from the top dead center to the bottom dead center. In the sequence it comes in the partial load operation to a decrease of the pressure in the expansion chamber 12 bottom atmospheric pressure. The combustion gas becomes “diluted” thereby before the implosion phase becomes introduced. The implosion phase becomes introduced, as soon as the piston 1 has the bottom dead center UT achieved, as cooling water becomes 12 injected into the expansion chamber. By the sudden cooling of the combustion gas it comes by it to an other decrease of the pressure in the expansion chamber 12, for which now also in case of the full load enterprise of the motor below the atmospheric pressure is appropriate. The piston 1 becomes moved by this negative pressure upward pulled and now by the bottom dead center toward the top dead center. Be-end to this movement at the beginning of still the combustion chamber exhaust valve 11 one keeps open, in order to make the charge exchange possible in the combustion chamber 7. The other upward motion of the piston follows, becomes 7 compressed with which the fresh air in the combustion chamber and in addition rises the pressure in the expansion chamber 12 toward atmospheric pressure. Short one before the piston 1 the top dead center achieved, rises the pressure in the expansion chamber 12 over the atmospheric pressure and the expansion chamber exhaust valve 30 becomes opened, whereby the incineration gas water mixture contained in the expansion chamber 12 is pressed out by the expansion chamber exhaust valve 30 (“exhaust phase”). With the reaching of the upper dead center OT of the piston 1 or short before it the made next ignition of the fuel in the combustion chamber. Up to its complete combustion the piston at the top dead center (“wait phase”) remains, on which by opening the exhaust valve 11 the next expansion phase introduced becomes.

[0025] In an other prefered operation a dilution of the combustion gas to below the atmospheric pressure is already provided in the full load enterprise, if the piston has the bottom dead center achieved.

[0026] The volume of the cylinder space 25 of the compressor pump 23 is larger around at least 25%, in a preferable embodiment around at least 50%, than it corresponds to the volume for a filling of the combustion chamber with a mixture, whose blending ratio exhibits an air number of lambda = 1, with an amount at fuel, injected with full load of the motor into the combustion chamber 7. It can become in each case thereby in connection with the throttlable air intake valve 24 both with low and with high speeds of the motor an air number of the mixture in the combustion chamber 7 of at least lambda = 1 achieved. The full load of the motor corresponds to the power output maximum with the respective speed, is designed for which the motor.

[0027] In place of the described throttled air intake valve 24 a throttled air intake valve z could. B. also in form of an electromagnetic valve performed become.

Legend to the reference numbers:

1 Piston
2 Shaft
3 inner cam surface
4 expresses cam surface
5 Bar
6 Roller
7 Combustion chamber
9 Spark plug
10 Unit
11 Combustion chamber exhaust valve
12 Expansion chamber
13 Flange
14 heat insulating layer
15 heat insulating layer
16 Cylinder head
17 Cylinder wall

18 Piston seal
19 Injection nozzle
20 Cushion
21 Compressor piston
22 Piston rod
23 Compressor pump
24 Air intake valve
25 Cylinder space
26 Valve disk
27 Valve stem
28 Piston
29 Air exhaust valve
30 Expansion chamber exhaust valve
31 Piston cylinder unit
32 Cylinder space
33 Unit
34 Spring
35 Sealing ring
36 Rotational axis
37 Lever
38 Pin
40 Piece of line
41 Water separator
42 Water tank
43 Exhaust
44 Roller
45 Cam disc
46 Roller
47 Lever
48 Cam disc
49 Pin
50 Lever
53 first portion
54 second portion
55 third portion
56 Spring means
57 Compression spring
58 Pressure plate
59 Screw
60 Line
61 Line
62 Surface
63 Surface